Aerospace Medicine Primary Course

Disposition of ECG Findings

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Good Morning!
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Overview

- General comments
- Normal variants - do not require any evaluation, locally or at ACS
- ECG findings requiring local evaluation
- ECG findings requiring ACS evaluation
- Specific ECG findings

General Comments

- Patient first, aviator second
- Evaluate as you feel clinically indicated
- Aeromedical evaluation per policies
- Call ECG Library for advice

  DSN 240-2861/3242, Comm 210-536-2861/3242
- We require actual tracings for review
- Usually continue flying during local testing

“It’s a very sobering feeling to be up in space and realize that one’s safety factor was determined by the lowest bidder on a government contract.”

Alan Shepherd

Normal Variants

- Sinus brady/tachycardia
- Sinus arrhythmia
- Ectopic atrial rhythm
- Junctional rhythm
- Wandering atrial pacer
- First degree AV block
- Mobitz I AV block
- R > S in V1 w/o RVH
- Idioventricular rhythm
- Incomplete RBBB
- Terminal cond. delay
- Nonspecific IVCD < .12
- Early repolarization
- Right axis deviation
- Indeterminate axis
- S1S2S3, RSR' V1, V2
- Sinus pause < 2-3 sec
- SV/Vent. escape beats

Local Evaluation

- L & R atrial abnormality
- L & R ventricular hypertrophy
- LVH by voltage only
- RBBB*
- L anterior/posterior hemiblock
- Bifascicular block (RBBB + hemiblock)
- L & R axis deviation
- Ectopy/pairing on ECG
- Frequent ectopy on Holter
- Rare/occ pairs on Holter
- Single SVT run 3-10 beats duration*
- Nonspecific ST/T changes
- Possible myocardial infarct
- Short PR 0.10 - 0.12 sec
- Sinus tachycardia
- Pericarditis

ACS Evaluation

- LBBB
- IVCD >120 msec QRS width
- Wolff-Parkinson-White (WPW) with or without SVT
- Short PR < 0.10 sec
- Recurrent nonsustained SVT
- Any sustained SVT
- Atrial fibrillation and/or flutter
- Nonsustained VTach
- Myocarditis

Chamber Dilation/Hypertrophy

- Atrial abnormality - ECG criteria poor
- RVH, biventricular hypertrophy, LVH with ST-T changes rare in this population
- LVH voltage alone common, probably not LVH by echo if normotensive
- Echo definitive study

Right Bundle Branch Block (RBBB)

- 0.2% prevalence - 122,043 aviators/applicants
- 0.6% prevalence active USAF aviators
- USAF study of 394 aviators with RBBB
  94% nl, 2.7% CAD, 2.4% HTN, 1.3% other
- Mean follow-up 11 years on the normals
  6% CAD, 6% HTN, 4% death, one heart block

RBBB - USAF Policy

- Since 1993, local evaluation only with treadmill, echo and Holter monitor
- Tests normal - indefinite, unrestricted waiver
- Brooks evaluation only if local tests abnormal
- Same policy for new RBBB or progression from incomplete RBBB

Left Bundle Branch Block (LBBB)

- 0.014% of 122,043 military aviators, none < age 25, rare age 25-35, most > age 35
- Prevalence parallels CAD and HTN
- USAF experience - 144 aviators with LBBB
  - 12 % SCAD, 6% MCAD, 3.5 % DCM
  - Another 5 % later developed DCM
  - Only one developed complete heart block

LBBB - USAF Policy

- ACS evaluation for both persistent and rate-related LBBB
- Full noninvasive evaluation, including nuclear stress imaging, plus cardiac catheterization
- If no underlying disease, unrestricted waiver and Brooks reeval q 3 yrs

Nonspecific IVCD

- QRS <120 msec, normal variant
- QRS >120 msec, 0.4% military aviators
  - Resembles LBBB more often than RBBB
  - Risk of underlying heart disease uncertain
  - More concern if new finding in older aviator
  - Less concern in younger aviator or if a stable finding since young age

IVCD - USAF Policy

- No data regarding long-term prognosis
- Hybrid of RBBB and LBBB
- Brooks evaluation with full noninvasive testing, including nuclear stress imaging
- No cardiac cath if noninvasives normal
- Unrestricted waiver and q 3 yr reevaluation

Hemiblocks & Bifascicular Block

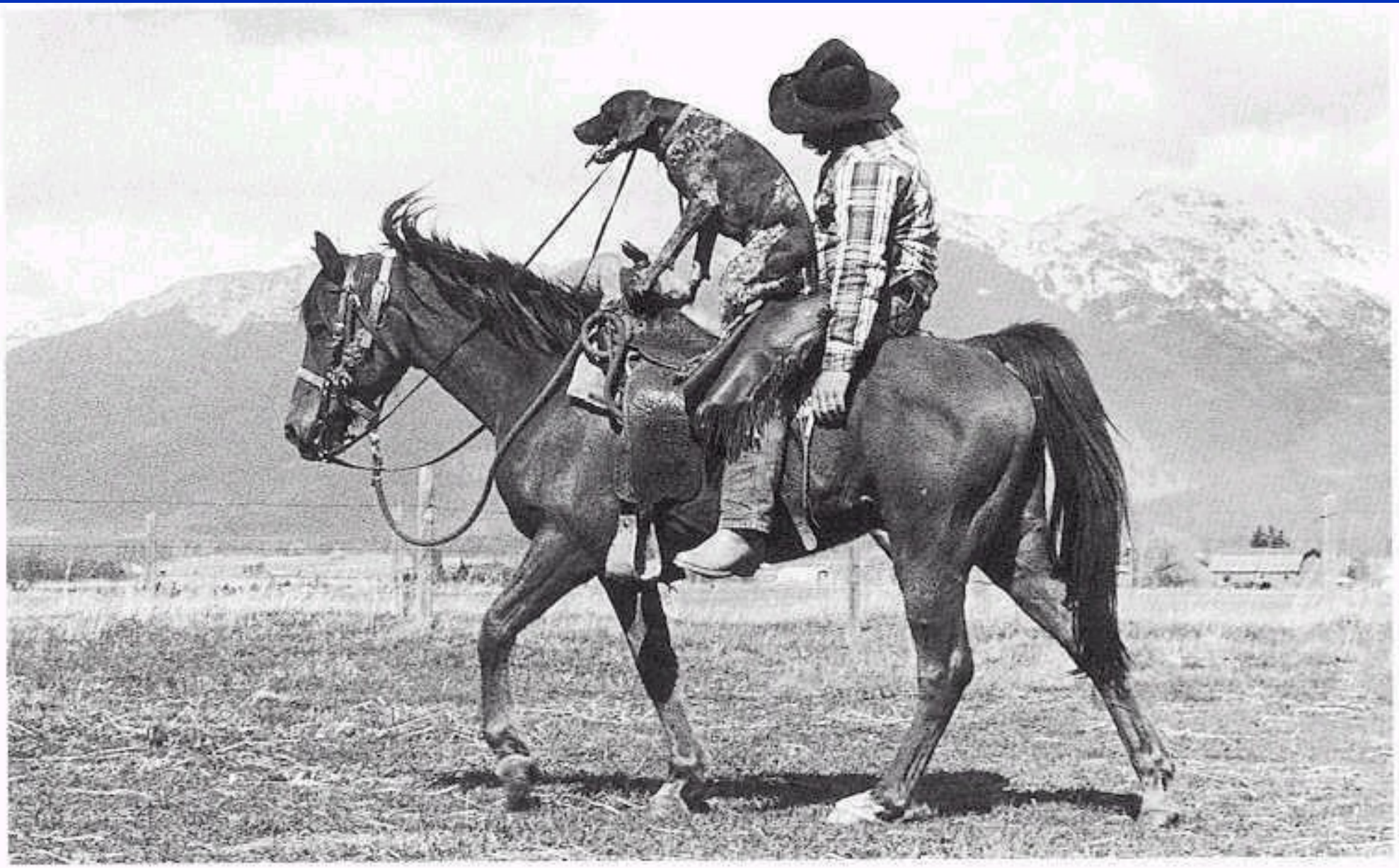
- LAHB 0.9%, LPHB 0.1% military aviators
  - Prognosis normal if no underlying disease
- Bifascicular block = RBBB + LAHB/LPHB
  - Prevalence in aviators not available
  - USAF study 394 with RBBB => incidence underlying disease same for RBBB with normal axis as for bifascicular blocks
- Noninvasive evaluation sufficient

Hemiblocks & Bifascicular Block USAF Policy

- Hemiblocks
  - Age $\leq$ 35 => echo locally
  - Age > 35 => treadmill, echo locally
- Bifascicular block (RBBB + LAHB/LPHB)
  - Currently same as RBBB
  - Previously same as IVCD with Brooks eval

Axis Deviation

- LAD 0.9% and RAD 0.07% of aviators
- Evaluate if new finding, esp. age > 35 yrs
- LAD - same as hemiblocks
  - Age $\leq$ 35 => echo locally
  - Age > 35 => treadmill, echo locally
- RAD - local echo, ?spirometry and/or CXR, if new finding in aviator > age 35



Ectopy in Aviators

- PACs - 0.6% of aviators and 0.4% to 3.0% of civilians on routine ECG
- PVCs - 0.8% of aviators and 2.0% to 7.0% of civilians on routine ECG

Supraventricular and Ventricular Ectopy

- Local 24 hour Holter monitor for:

  PACs, PJCs, PSVCs

  PAC pair, PJC pair, PSVC pair

  Uniform or multiform PVCs

  PVC pairs

Holter Monitor Disposition

- Rare ectopy = $\leq$ 0.1 % of total beats
- Occasional = > 0.1 % and $\leq$ 1.0 %
- Frequent = > 1.0% and $\leq$ 10%
- Very frequent = > 10%
- Rare pairs = 1 to 5 pairs
- Occ pairs = 5 to 10 pairs
- Freq pairs = > 10 pairs

Holter Monitor Disposition

- Rare/occ ectopy => no further evaluation
- Frequent ectopy => local treadmill, echo
- Very frequent ectopy => Brooks evaluation
- Rare/occ pairs => treadmill, echo
- Frequent pairs => Brooks evaluation

Supraventricular Tachycardia (SVT)

- One 24 hour holter monitor
- Only one SVT run of 3 - 10 beats length
  - age < 35, no further tests, indefinite waiver
  - age ≥ 35, local echo and treadmill
- Multiple SVT runs or a single run longer than 10 beats duration => Brooks eval
- Includes SVT, atrial fibrillation, atrial flutter

Ventricular Tachycardia (Vtach)

- Clinically appropriate evaluation
- Sustained Vtach DQ without waiver
- Any duration Vtach with associated hemodynamic sxs DQ without waiver
- Asx, nonsustained Vtach and no apparent underlying heart disease, one Holter monitor and Brooks evaluation

Possible Ischemic Changes

- Nonspecific ST-T wave changes
  - present in 0.9% of military aviators
- Concern if new compared to prior ECGs
- Repeat ECG in fasting state
- Persistent serial change
  - Age $\geq$ 35 => treadmill
  - Age < 35 => echo only

Possible Myocardial Infarction

- Comparison to prior ECGs important
- Diagnostic ECG changes - must confirm
  - treadmill alone inadequate
  - stress echo or stress nuclear imaging
- Nondiagnostic ECG changes
  - Small inferior Q waves or poor R wave progression anterior V leads
  - Judgment call

Miscellaneous

- Short PR, no delta wave: PR 0.10 to 0.12 sec, no SVT by hx => nl variant. PR < 0.10 sec => Brooks evaluation
- Mobitz II & complete AV block => DQ
- Sinus tachycardia - don't send the ECG! Resolve issue of persistent ST locally

Don't
mess with
Texas.

Tachyarrhythmias Concerns

- Supraventricular tachycardia (SVT)
- Ventricular tachycardia (VT)
- Atrial fibrillation (AF)
- Hemodynamic symptoms
- Recurrent sustained episodes
- Therapy (ablation, medications)

Tachyarrhythmias

- Supraventricular and ventricular

  ≥ 3 consecutive beats, rate ≥ 100 bpm

- Sustained and/or with associated hemodynamic symptoms disqualifying
- Problem – asymptomatic, nonsustained

  What are the aeromedical concerns?

Nonsustained Tachyarrhythmias

- Are they a risk factor for underlying organic heart disease
- Are they a risk factor for arrhythmic events and other cardiac endpoints
- Are they a risk factor for sustained tachyarrhythmias
- If not, then no aeromedical concern

SVT in US Military Aviators

- 430 aviators (428 males, 2 females)
- Mean age 40.3 males, 30.4 females
- Mean follow-up 11.4 years
- 42 (10%) hemodynamic symptoms
- 21 (5%) asx recurrent sustained SVT

SVT in US Military Aviators

- Multiple cofactors not predictive
- SVT characteristics not predictive
- Frequent / paired ectopy not predictive
- Pre-excitation (WPW) predictive
- Recurrent sustained SVT predictive

Sustained SVT - Recurrence

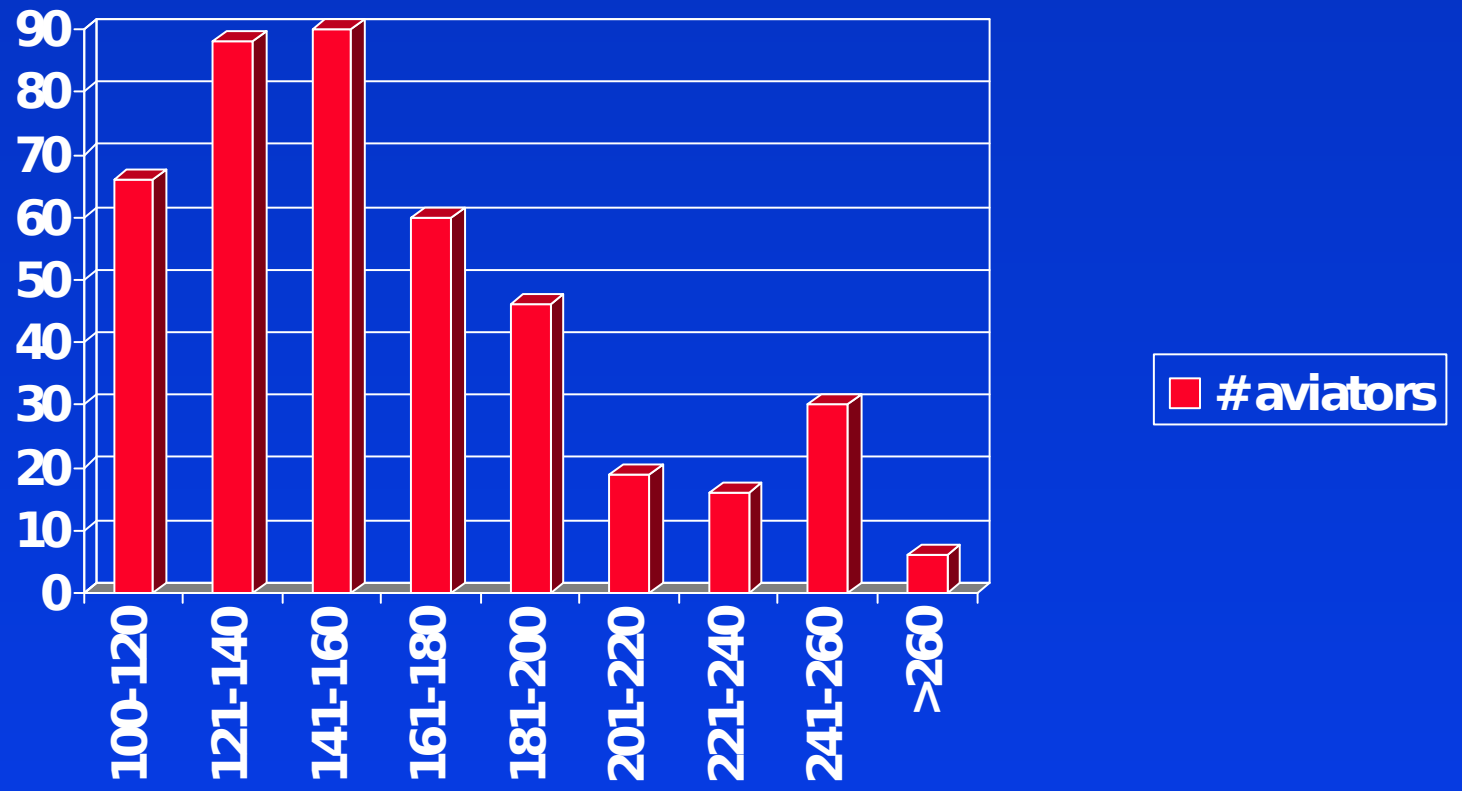
- Ablation literature: 71% at 3 months
- Population study:

  6% at 3 months, 15% at 1 yr, 20% at 2 yrs
- USAF - future sustained SVT
  - nonsustained SVT.....0.9% total
  - single sustained SVT.....1.0% per year
  - recurrent sustained SVT.....2.0% per year

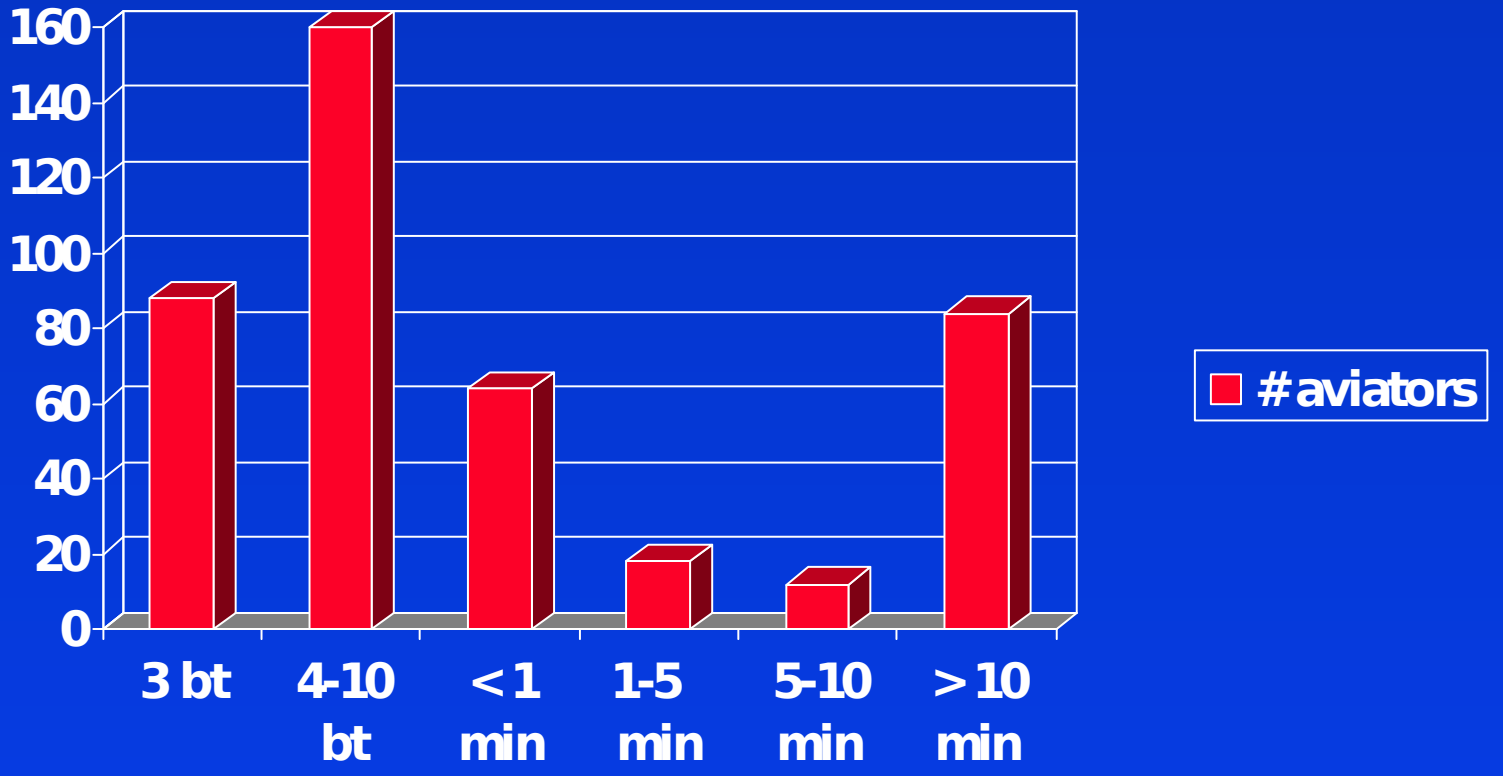
SVT - What we do

- SVT + hemodynamic symptoms DQ
- Recurrent sustained SVT disqualifying
- SVT with pre-excitation disqualifying
- Generally, all other SVT waiverable
- Other considerations may apply if there is underlying heart disease

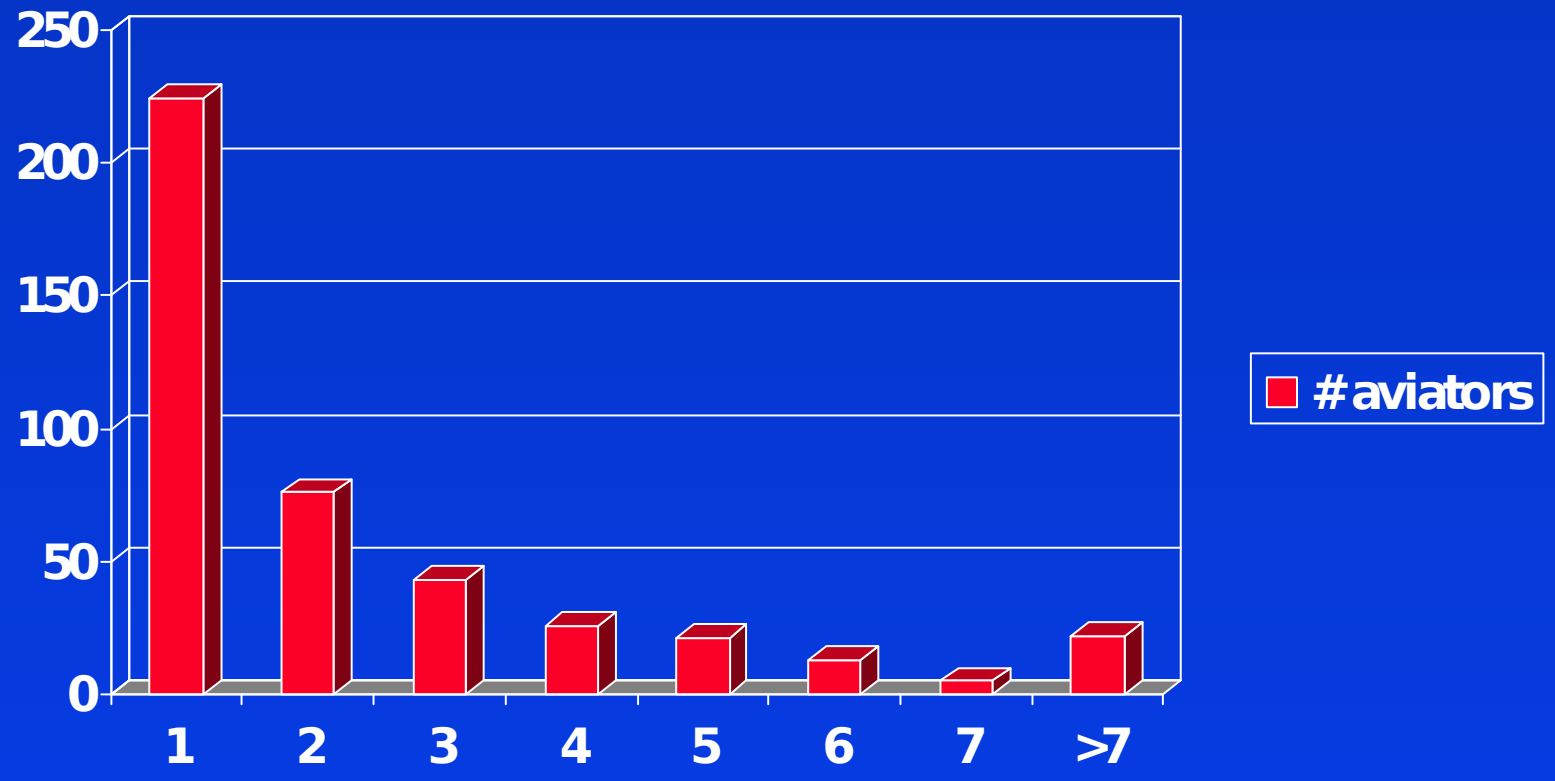
Rate Fastest SVT Run



Duration Longest SVT Run



Number of SVT Runs



“When once you have tasted flight, you will forever walk the earth with your eyes turned skyward, for there you have been, and there you will always long to return.”

Leonardo da Vinci

Lone atrial fibrillation (AF)

- No heart disease or HTN, age < 60
- Single episode, paroxysmal, chronic
- Thromboembolism, symptoms from AF
- Stroke risk < 1% per year
- Single & paroxysmal benign, chronic ??

Lone AF

- Impaired cardiac performance
  - loss of atrial contribution & AV synchrony
  - rapid ventricular response to exercise
- Operational consideration
- Paroxysmal AF may be a greater concern than chronic
- Disposition like SVT

Lone AF – ACS Review

- 279 aviators, mean age 37 (range 20-59)
  223 (80%) isolated, 34 (12%) paroxysmal (PAF),
  22 (8%) daily/chronic (CAF)
- 19 years mean f/u on 241/279 (86.4%)
  129 (53.5%) still isolated, 84 (34.9%) PAF,
  28 (11.6%) CAF
- Initial presentation vs final f/u:
  Isolated – 67% still isolated, 32% PAF, 1% CAF
  Paroxysmal – 48% no recur, 31% PAF, 21% CAF

Lone AF – ACS Review

- Annual event rates stroke/stroke plus hemodynamic symptoms, before age < 60
  - Isolated - 0.04% per year/0.55% per year
  - PAF - 0.00% per year/0.85% per year
  - CAF - 0.00% per year/0.00% per year
- Annual event rates to end of follow-up
  - Isolated - 0.14% per year/0.51% per year
  - PAF - 0.32% per year/0.81% per year
  - CAF - 1.07% per year/1.07% per year

Atrial Flutter

- Uncommon as an isolated rhythm, usually associated with AF
- Rapid rate response of 300 bpm due to 1:1 conduction is possible
- Requires meds for rate control
- DQ, treat like SVT or treat like AF

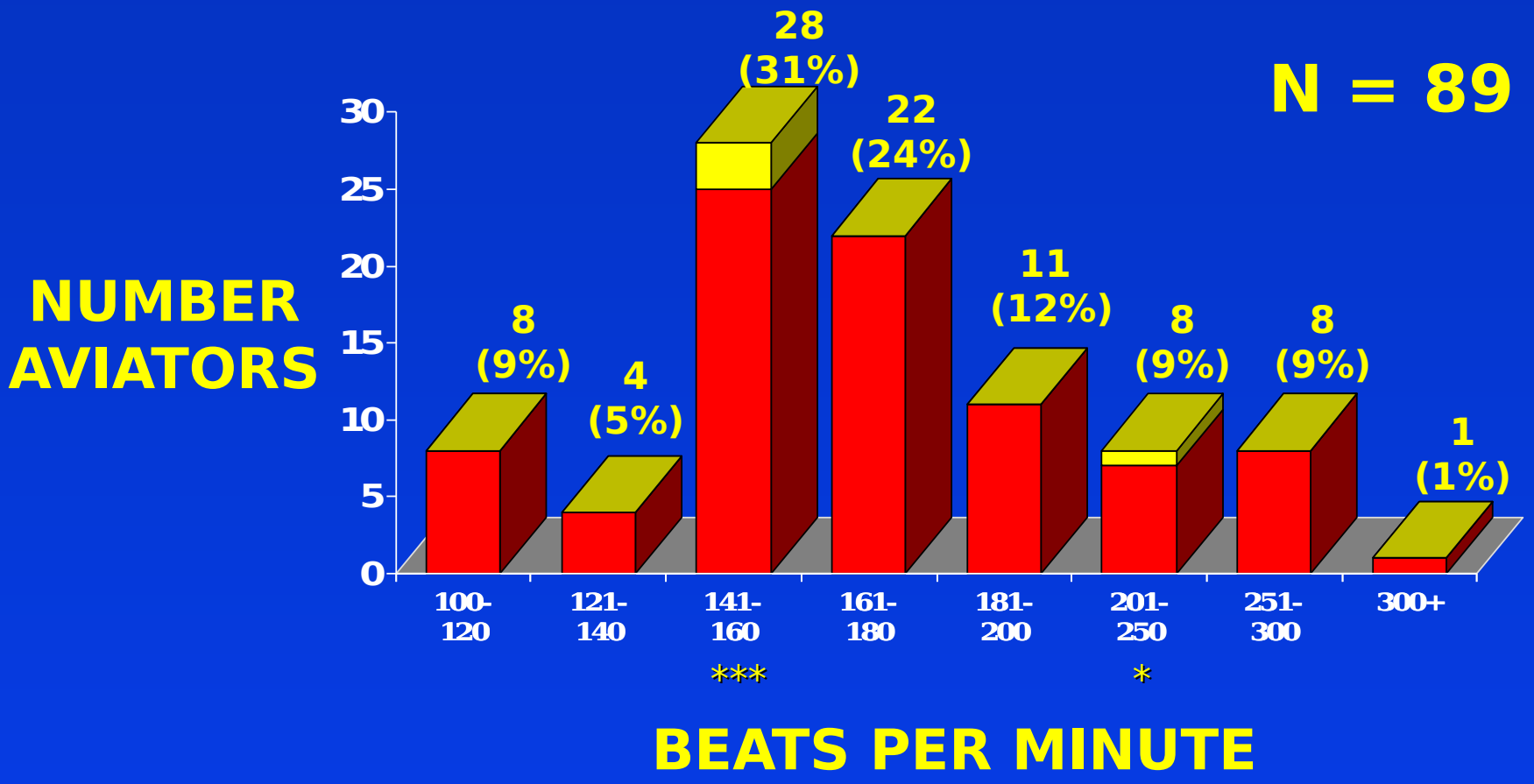
VT in US Military Aviators

- 193 aviators (192 males, 1 female)
- Mean follow-up 10.6 years
- 103 idiopathic VT
- 9 (4.7%) hemodynamic symptoms
- No documented sustained VT

Idiopathic VT

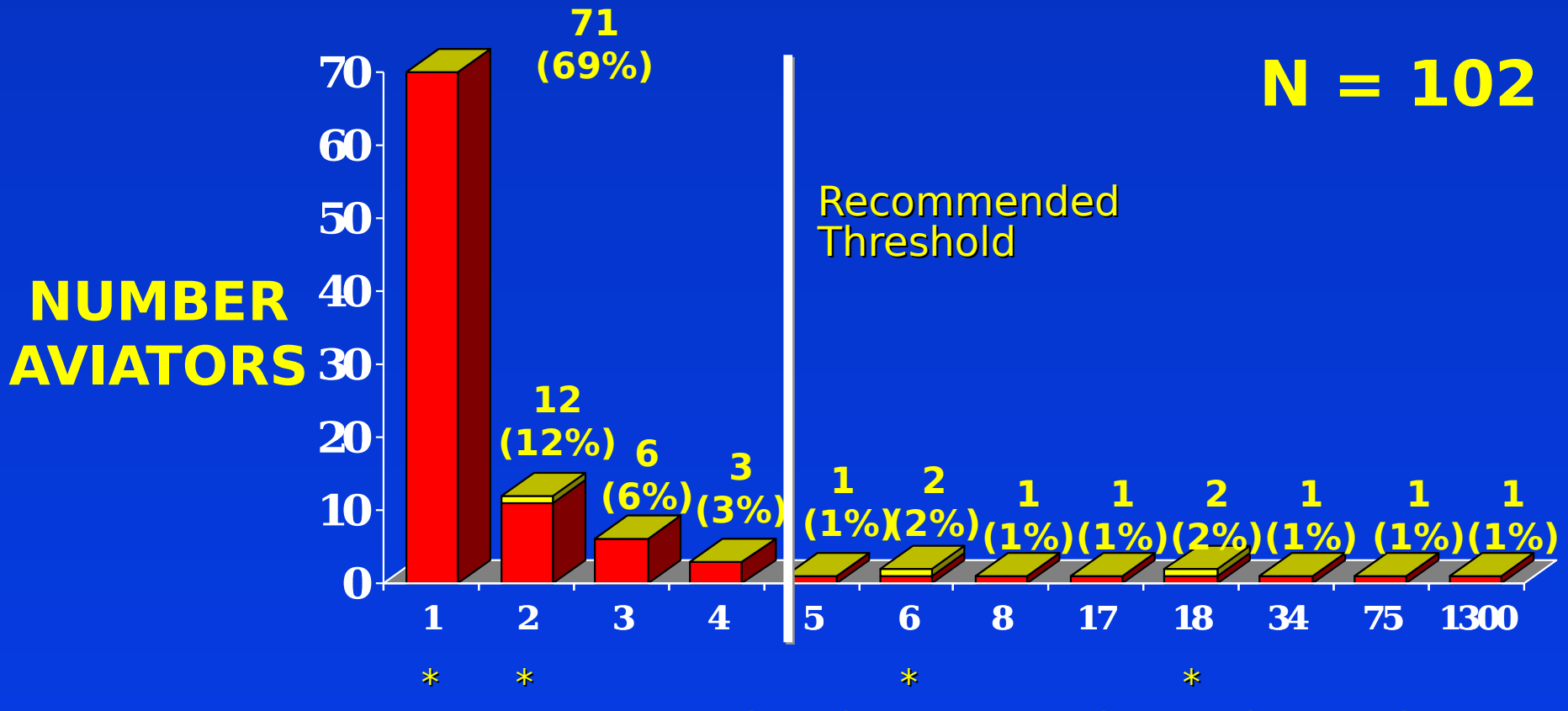
- Multiple cofactors not predictive
- VT characteristics not predictive
- Frequent / paired ectopy not predictive
- So, why not let all asymptomatic idiopathic nonsustained VTach fly?

VT - Heart Rate of Episode



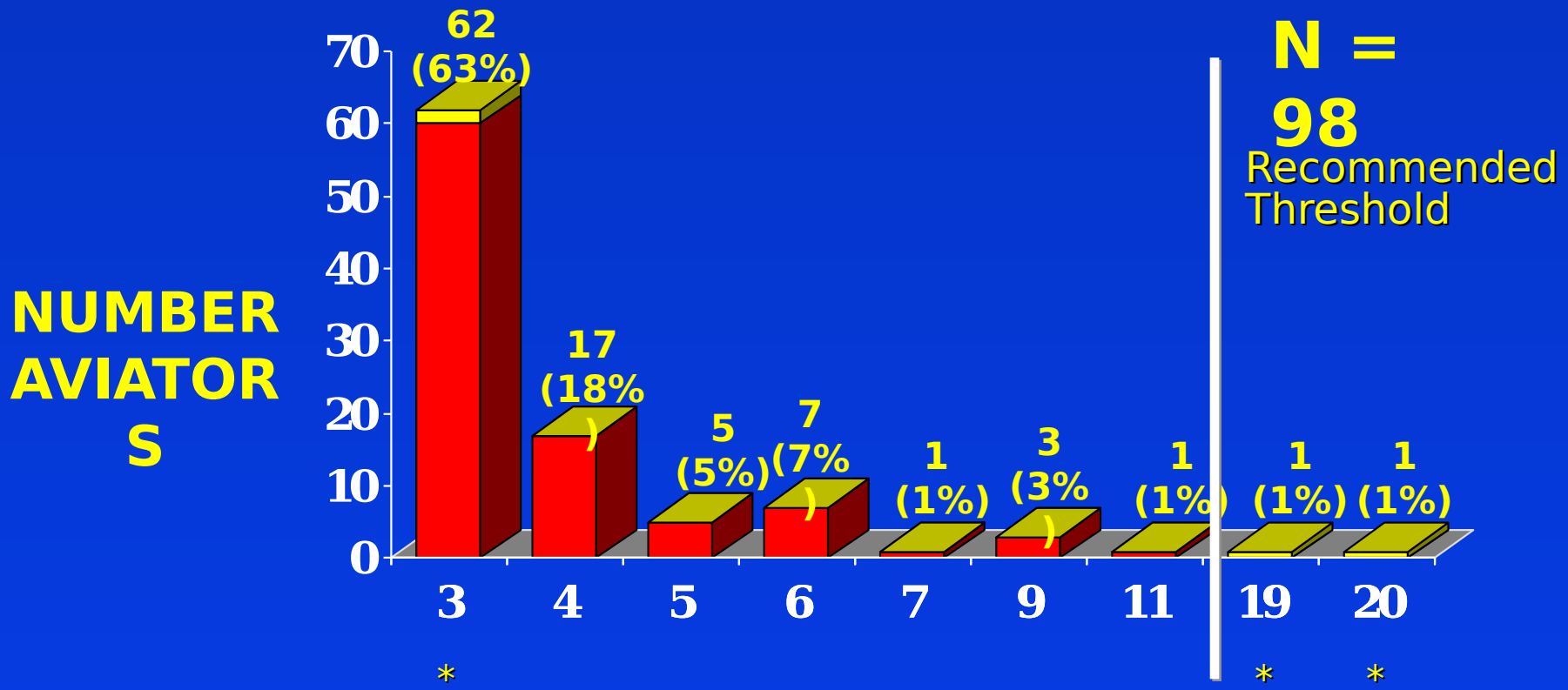
* = AVIATOR WITH HEMODYNAMIC SXS

VT - Number of Episodes



* = AVIATOR WITH HEMODYNAMIC SXS

VT - Length of Episode



“The regret on our side is, they used to say years ago, we are reading about you in science class. Now they say, we are reading about you in history class.”

Neil Armstrong, July 99

FC IIA Waiver

- 11 beats longest VT run
- 4 episodes VT per evaluation (Holter/TM)
- Substrate of PVC pairs/frequent PVCs - OK
- Cardiac cath only for abnormal noninvasives
- ACS noninvasive re-evaluation yearly times two, then every 3 years

FC II Waiver

- 11 beats longest VT run
- One episode VT total
- Substrate disqualifying
- Monitored centrifuge initial evaluation
- ACS noninvasive re-evaluation yearly times two, then every 3 years

VT and the Cardiac Literature

- Nonsustained VT benign prognosis
- Frequency, pairing and VT combined often
- What endpoints are considered
- Benign prognosis compared to what group
- A few episodes of short duration VT benign
- Other sources recommend 10 beats cutoff

Accessory Pathways (AP)

- Pre-excitation, WPW, bypass tracts
- Conditions with AP of AV conduction
- Concerns - risk sudden death & SVT
- SVT in 12%-80% WPW ECG pattern
- Sudden death 1%-6% over 10 years
- No reliable identifiers of high risk

SVT and APs

- 10% SVT at age 20-39, 36% age > 60
- Community populations - 53% and 58%
- USAF & USN aviators - 12%-16%
- 0.3%-3.0% per year for 10 yrs after dx
- Mayo Clinic - 3% per year for 10 yrs
- USAF - 0.7%/yr pattern, 2%/yr syndrome

WPW - What we do

- WPW pattern (ECG pattern, no SVT)
  - DQ for undergraduate flying training
  - Unrestricted waiver trained aviator
- WPW syndrome (ECG pattern + SVT)
  - DQ for training and continued flying

That’s All, Folks!

“Flying an airplane with only a single propeller to keep you in the air. Can you imagine that?”

Captain Jon Luc Picard

'*Star Trek: The Next Generation*'

Ablation - Aeromedical Issues

- Immediate complication and success rates somewhat irrelevant
- Long term success rate (recurrence)
- Late complications (arrhythmogenic?)
- What is required to verify success
- Is it a cure?

Accessory Pathways and RFA

- Immediate success rate $\geq$ 90%
- Complication rate 3%-5%, most minor
- Complete heart block 0.5% all AP RFAs; 5%-10% of APs on anterior surface of AV node; these have a risk of 5%-10% for complete block
- Recurrence 5%-10%, most in 2-4 months
- No false negative f/u EPS after 30 days

Accessory Pathways and RFA

- No literature with ≥ 5 years follow-up
- Consulted five leading RFA experts
- Late recurrence rare, esp w/ neg EPS
- RFA site not arrhythmogenic
- No other late problems/complications

RFA of PSVT

- Most PSVT (60%) - reentry in AV node
- Success similar to APs (30% of SVT)
- Success 95%+, recurrence 5%
- Complete heart block risk 1%

  RFA on posterior surface of AV node
- Waiver policy extended to PSVT

RFA of SVT - What we do

- Follow-up EP study $\geq$ 90 days after RFA to verify success
- Noninvasive reevaluation every 3 years
- For flying training, screening echo before RFA to exclude other disqualifying diagnoses

RFA of other SVTs

- Focal automatic atrial tachycardia, intra-atrial reentry tachycardia, atrial flutter and atrial fibrillation
- Promising but less data in literature (numbers and long-term experience)
- Associated heart disease more likely
- Case by case or DQ without waiver

Atrial Tachycardias

- Primary success 80 - 100%
- Significant complications 0%
- Recurrence rates 0%-30%
  numbers in literature small, recurrence rate probably low and comparable to other SVTs
- Need better data for waiver policy

Atrial Flutter

- Primary success rate 85%-90%
- Significant complications 0%
- Recurrence 5%-40% up to 7 months
- Possible 1:1 conduction w/ recurrence
- Also possible late risk atrial fibrillation (primarily if atrial fibrillation pre-ablation)

Atrial Fibrillation

- Least data/experience of all SVTs
- Consider “investigational”

  Control ventricular rate by AV node modification, Cure by ablation version of maze procedure, or Cure by focal RFA, usually near pulmonary veins
- Too early for any waiver policy

RFA of Idiopathic Ventricular Tachycardia (IVT)

- More recent than SVT ablations
- Success depends on type/site of IVT
- AHA/ACC Class III (not recommended) for asymptomatic, nonsustained, “benign” IVT; Class II (may be helpful) for symptomatic nonsustained IVT

Experience comparison

- 1993 NASPE survey
  AVRT……5,400 patients reported
  AVNRT……5,400 patients reported
  IVT……800 patients reported
- One center's first 1022 RFAs
  480 PSVT, 429 APs, 36 VTach

Literature Review

- 18 studies 1993 - 1997, 325 patients
- Largest two studies 57 and 48 pts
- 9 of the 18 studies $\leq$ 10 patients
- Mean ages ranged from 11 to 57

Literature Review

- Overall success 75 - 100%
- 63 - 100% depending on site/type IVT
- Complications 4.4%
- RV perforation, AI, MR, effusion, RBBB
- Recurrence 7% ($\leq$ 8 Months), including 1 sudden cardiac death

RFA - IVT Literature Problems

- Small numbers, “poor” follow-up
- Clinical f/u only - sxs, recurrent VT
- Pts “stable” but sxs, drug failures
- No routine EPS, TM, HM, etc. f/u
- Mapping & RFA depends on IVT
- Followed experience of RFA of SVTs

RFA of IVT - Summary

- Success/comp/recurrence c/w SVT
- Different mechanisms, considerations
- Problem documenting success
- Not yet comfortable to recommend waiver for flying duties or training
- Need more and better data

USAF School of Aerospace Medicine

Aeromedical Case Presentations

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Which requires ACS evaluation?

- Sinus arrhythmia
- RBBB
- LBBB
- PVC on ECG
- New ST-T waves on fasting ECG

Which is not a normal variant?

- ST elevation (early repolarization)
- Wandering atrial pacer
- Sinus bradycardia
- LBBB
- rSR’ in leads V1/V2

Aviator with PVCs

- Routine ECG on an F-15 pilot's flight physical has 2 multiform PVCs
- You request Holter monitor

  Frequent multiform PVCs => ?

  Very freq PVCs & freq PVC pairs => ?

  Four beat run of Vtach, asx => ?

Case - ST changes

- 47 y.o. O-6, F-15 Command Pilot
- 4200 total military flying hours
- ECG on routine flight physical - ST-T wave changes inferior leads
- What next?

Case - ST changes

- ST-T wave changes new
- Repeat fasting ECG unchanged
- Local treadmill abnormal - no symptoms but 1.5 mm ST depression inferolateral leads
- What next?

Case - Palpitations

- 24 yo male C-130 pilot
- Driving by clinic – rapid heart sensation, pulls over and pulse 200 bpm => clinic treatment room
- ECG shows SVT, after conversion to sinus rhythm, ECG shows WPW
- What next?

Case - LVH on ECG

- 28 y.o. pilot with increased voltage on routine ECG
- No old ECGs available
- Very active athletically - cycling and weight training
- Normal blood pressures now & prior

Case - LVH on ECG

- Echo with mild concentric LVH - 12 mm septum and post wall (nl $\leq$ 11)
- What next?
- What if echo showed moderate concentric LVH with 14-15 mm wall thickness?

Case - LVH on ECG

- Nl LV thickness 7-11 mm
- 6-10 mm (female) and 7-12 mm (male) DCIEM pilot training applicants
- Rare > 14 mm, even in elite athletes
- Reasonable to accept 12-13 mm in appropriate scenario
- Resolves with serial q4 week echos - IF the subjects stops ALL exercise

Case 8 - PVCs

- 24 yo pilot - several PVCs on routine ECG
- Asx, according to technician
- What next?

Case - PVCs

- Holter very frequent multiform PVCs (23%) and frequent pairs
- Exam soft S3 and 2/6 systolic murmur
- Competetive level athlete & martial arts
- Treadmill - nl ST response, increased PVCs
- Echo mod dilated LV/LA, mildly dilated RV/RA, depressed LV function, mild MR

Case - Viral Illness

- 2 months ago severe viral illness with fever, constitutional symptoms, dyspnea, palpitations and positional chest pain
- Went to a nearby “Doc-in-the-box”, treated with NSAID, nasal & oral decongestants
- Records not helpful; ECG diffuse mild ST elevation read as normal variant early repolarization

Case - Myo/Pericarditis

- Seasonal peak - winter for myocarditis, fall and spring for pericarditis
- Coxsackie and echo viruses common both
- Subclinical to fulminant congestive failure
- Sxs resolve within a few weeks, chamber sizes & function may take several months
- Usually resolve, but may progress to a dilated cardiomyopathy

Case - Myo/Pericarditis

- Discontinue flying duties
- Discontinue all exercise
- Serial echos and Holters every 2 months
- Chamber sizes and LV function progressively return to normal and PVCs resolve by 6 months after viral illness

Case - Myo/Pericarditis

- Return to flying duties?
- Unrestricted or as-or-with-copilot?
- Requirement for reassessment?

Case 11 - WPW

- 38 y.o. pilot w/ 3 episodes rapid heart beat, each w/ exercise
- 12/91 & 1/92 - 15 & 60 min, dyspnea
- 02/92 - 11 hrs, dyspnea, fatigue, chest pressure, diaphoresis => ER
- SVT 220 bpm, => NSR & WPW

Case - WPW
More History

- 2/92 RFA lateral AP, EPS post RFA no functioning AP, nl ECG
- Holter 8/92 - 4 runs SVT, 3-7 beats, max rate 163 bpm, asx
- 1/93 EPS residual AP, repeat RFA
- 3 f/u Holters without any SVT

Case - WPW
Even More History

- ACS 10/93 - nl TM, nl thal, nl echo, neg fluoro, Holter 3 beat SVT
- f/u EPS - no functional AP and no inducible SVT
- SVT treated as “regular” SVT
- Unrestricted waiver, reeval 1 yr

Case - WPW
Guess What?

- ACS 11/94 - Holter 11 beat SVT, other studies unchanged
- ACS 11/95 - Holter 3 beats SVT, other studies unchanged
- Both reevals unrestricted waiver
- Reeval 11/98 normal, no SVT

Case 12 - New Q waves

- 54 yo Lt Gen, C-141/C-5 Command Pilot with 5,000 hours
- Routine ECG sent to ACS/ECG Library - new inferior Q waves
- Not present on yearly ECGs, but no ECG sent last year

Case - New Q waves

- ECGs read as normal locally
- Episode of chest tightness, dyspnea 18 months ago dx'ed as viral URI
- Treadmill by local USAF cardiologist normal - no symptoms or ECG changes

Case - New Q waves

- ACS review of studies
- ECG one year ago - same Q waves
- Local treadmill abnormal - 2mm flat and downsloping ST depression inferolateral leads
- ACS evaluation

Case - New Q waves

- Treadmill - ST depression, no sxs
- Fluoroscopy positive proximal LAD
- Thallium inferior fixed defect, anterior reversible defect
- Cath - significant 3 vessel disease, normal overall LV function, inferior hypokinetic segment

Case - New Q waves

- Bypass surgery - LIMA graft to LAD, three saphenous vein grafts to CX (circumflex) and RCA systems
- 6 months later asx, treadmill normal, thallium normal except small residual inferior fixed defect
- Requests return to flying status